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Estimation of Dissipation Rates and Bottom Stress in the Coastal Ocean
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John H. Trowbridge

Abstract

The work funded by this grant addressed robust methods for estimation of dissipation rate and Reynolds stress based on turbulence measurements in the coastal ocean. The work resulted in two publications. The first was an evaluation, based primarily on intensive laboratory tests, of the acoustic Doppler velocimeter (ADV) as a turbulence sensor. The second was a description, based on theoretical considerations and a field test, of a novel technique for measuring Reynolds stress in the presence of surface waves, which involves differencing measurements obtained from spatially separated sensors.

Text

The work funded by this grant addressed robust methods for estimation of dissipation rate and Reynolds stress based on turbulence measurements in the coastal ocean. The work had two components: (1) an intensive test of the acoustic Doppler velocimeter (ADV), manufactured by Sontek, Incorporated, of San Diego, California; and (2) theoretical and field evaluation of a technique for measuring turbulent Reynolds stress in the presence of surface waves.

The evaluation of the ADV consisted of a set of measurements in steady turbulent flow in a laboratory flume with well characterized flow conditions. The evaluation focused on measurement of the mean velocity, direct estimates of the components of the Reynolds stress tensor, and the behavior of the velocity spectrum at high frequencies, which can be used to obtain indirect estimates of dissipation. A laser-Doppler velocimeter (LDV) served as a standard for comparisons. The analysis also focused on viscous effects and on the spatial filtering due to the finite sample volume of the ADV, both of which could be seen in the high-frequency part of the velocity spectrum. The conclusion is that the ADV is an excellent sensor for obtaining direct covariance measurements of turbulent Reynolds shear stress, provided that the noise levels associated with the three acoustic paths are sufficiently nearly equal, and that the ADV provides high-quality indirect estimates of turbulence dissipation from the inertial-range part of the velocity spectrum, provided that the component of the velocity is chosen to minimize noise and also provided that sufficient attention is given to spatial filtering and viscous effects. This work is described in a publication by G. Voulgaris and J. H. Trowbridge (Evaluation of the Acoustic Doppler Velocimeter (ADV) for Turbulence Measurements, J. Atmos. Oceanic Technol. 15, 272-289, 1998).

The work on estimation of Reynolds stress in the presence of surface waves was motivated by the fact that stress estimates from single sensors are irrevocably contaminated by surface waves if there is even a small uncertainty in the orientation of

either the sensor or the principal axes of the wave-induced velocity field. This problem typically cannot be overcome by analysis in the frequency domain, because surface waves and turbulence typically occupy the same range of frequencies in coastal applications, but there is typically a large disparity in scales of surface waves and turbulence, particularly near the sea floor, that permits separation of waves and turbulence and accurate estimation of Reynolds stress by means of a new technique. The technique is simply to use two velocity sensors, separated by a distance small in comparison to the surface wave length but larger than the correlation scale of the turbulence. With sufficient scale separation, minus the density times half of the covariance between horizontal and vertical velocity differences is a nearly wave-free estimate of the turbulent Reynolds shear stress. A detailed theoretical analysis indicates that this technique has small biases if properly applied under typical coastal conditions, and a field evaluation based on velocity measurements in shallow water indicates that the technique works well in practice. This work is described in a publication by J. H. Trowbridge (On a Technique for Measurement of Turbulent Shear Stress in the Presence of Surface Waves. J. Atmos. Oceanic Technol. 15, 290-298, 1998).